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STATE OF THE ART CONTINGENCY ANALYSIS (SOTACA) MODEL TECHNIQUES

SEPTEMBER 1987

PREPARED BY
STRATEGY AND PLANS DIRECTORATE

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The node-arc network structure of the State of the Art Contingency Analysis (SOTACA) Model allows the representation of processes or activities which consume time as well as the standard portrayal of movement of forces. This allows the user to observe the results of staff planning estimates in a sandtable-like manenr wherein events are depicted in time as well as in location.

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STATE OF THE ART CONTINGENCY ANALYSIS (SOTACA) MODEL TECHNIQUES

September 1987

Prepared by

Strategy and Plans Directorate

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DEPARTMENT OF THE ARMY
US ARMY CONCEPTS ANALYSIS AGENCY
8120 WOODMONT AVENUE
BETHESDA, MARYLAND 20814-2797

REPLY TO
ATTENTION OF:

CSCA-SPC (5-5d) 21 September 1987

MEMORANDUM FOR: Director, US Army Concepts Analysis Agency, 8120 Woodmont Avenue, Bethesda, MD 20814-2797

SUBJECT: State of the Art Contingency Analysis (SOTACA) Model Techniques

1. The SOTACA Model's straight-forward architecture and ease of application contribute to its growing acceptance and use as a planning aid. User innovation in applying the model will ensure that SOTACA remains a viable and responsive tool.

2. This paper documents one such innovative application of SOTACA. It permits the description of an operation in terms of time and spatial relationships by breaking the operation down into a sequence of logical elements, each of which can be examined as an activity that consumes time and resources. SOTACA provides the visual framework for portraying the staff planning time estimates of these elements. The resulting sandtable model (displayed on a computer screen) describes the connections in time and space among the activities involved in the operation, permitting the user to achieve a more analytical approach to the "mental wargaming" aspects of the planning process.

3. It has been my experience that the value imparted by SOTACA comes as much from the process of creating a "model" of an operation in SOTACA as in running it. I encourage other SOTACA users to look for innovative applications, and in that spirit, I commend this paper to you.

GERALD WILKES
MAJ(P), AD
Study Director

STATE OF THE ART CONTINGENCY ANALYSIS (SOTACA) MODEL TECHNIQUES	**STUDY SUMMARY CAA-TP-87-12**

THE REASON FOR CONDUCTING THE STUDY was to document a nonstandard use for the State of the Art Contingency Analysis (SOTACA) Model developed by the Conflict Analysis Center.

THE PRINCIPAL ACCOMPLISHMENT of the study was the development of a methodology by which time-oriented processes can be represented in SOTACA.

THE PRINCIPAL FINDINGS of the study were that:

(1) Time-oriented processes can be represented in conjunction with spatial movement in SOTACA.

(2) The combination of spatial and time representation in SOTACA allows a planner to portray the results of staff planning estimates dynamically in a sandtable-like manner.

THE PRINCIPAL LIMITATIONS of this use of SOTACA are that:

(1) SOTACA's network basis is a simplification of the operation described.

(2) This technique only uses the model as a framework to reflect the results of staff planning.

THE BASIC APPROACH was to exploit the node-arc structure of SOTACA to represent the passage of time without spatial movement in the model. This was done by distinguishing between nodes and arcs that represent movement from one place to another and those that only represent the time required to complete an activity or process.

THE STUDY SPONSOR was the Director, US Army Concepts Analysis Agency.

THE STUDY was conducted by MAJ Gerald J. Wilkes, Conflict Analysis Center, US Army Concepts Analysis Agency.

COMMENTS AND QUESTIONS may be forwarded to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-SP, 8120 Woodmont Avenue, Bethesda, MD 20814-2797.

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STATE OF THE ART CONTINGENCY ANALYSIS (SOTACA) MODEL TECHNIQUES

1. INTRODUCTION

a. Background. The Conflict Analysis Center (CAC) of the US Army Concepts Analysis Agency's Strategy and Plans Directorate investigated the use of the State of the Art Contingency Analysis (SOTACA) Model as a tool to explore low intensity conflict (LIC) problems. SOTACA is being developed as part of the Modern Aids to Planning Program (MAPP) which is sponsored by the Organization of the Joint Chiefs of Staff (OJCS). As such, it represents a model which will be provided to unified and specified commanders, some of whom are concerned with LIC issues/problems.

b. Purpose. The purpose of this paper is to describe the ideas and techniques which emerged from CAC's initial use of the SOTACA Model.

c. Scope. The generic scenario considered by CAC included the marshalling of appropriate forces, transporting them to some geographic location, moving them to an objective (infiltration), conducting actions on the objective, and withdrawing the forces (exfiltration). Force size was contemplated to vary from a few people organized as a team to upwards of a multibattalion task force. Sources of transportation might include aircraft, boats, vehicles, and foot movement in appropriate combinations. Operations were generally viewed to be characterized by stealthy infiltration, violent operations on the objective, and rapid exfiltration.

2. SOTACA MODEL OVERVIEW

a. The intent in developing the SOTACA Model was to provide a working model to the unified and specified commands to assist in mission planning.

b. SOTACA is a network model. Geographical locations are nodes, and connecting paths (roads, air routes, sea lanes, etc.) between nodes are called links. Links (usually termed "arcs" by mathematicians) can be traversed in either direction by a "task force". A task force is an entity of any size--a person or an army group--which traverses links defined by length (distance), type, and condition. Link conditions are model-limited to seven types (road, air, rail, river, lake, sea, and cross-country) and three conditions (poor, fair, and good). The speeds associated with a specific link type and condition pair are user-defined.

c. Paths taken by a task force through the network are either shortest route (given a network) or user-defined (a specific set of connecting nodes and links). A task force moves in user-defined time steps (e.g., 10 minutes, 8 hours, 2 days); once set, time step lengths are uniform throughout a model run. Task force current locations are graphically displayed at the end of each time step.

d. The SOTACA network is displayed against a geographical background drawn from the Central Intelligence Agency's Worldwide Database II, which displays coastlines, lakes and rivers, and political boundaries. The nodes are entered as latitude/longitude coordinates and are accurately displayed against the generated map background. Links automatically display the straight-line distance in kilometers between nodes. However, link distances can be increased to represent actual distance instead of straight-line distance for any particular link.

e. SOTACA has an attrition mechanism based on a pairwise comparison methodology that allows "combat" (force attrition) to take place between opposing forces at network nodes. The attrition mechanism permits conflict between disparate force elements (e.g., infantry battalion versus civic action team).

f. This investigation used SOTACA Version 2.7A. During the study, SOTACA 2.9 was released. It includes aerial combat, improved file handling, and built-in postprocessing graphics, among other improvements.

3. APPLICATION

a. General

(1) The generic mission was approached as a two-level modeling problem with SOTACA. At one level, SOTACA nodes represent physical locations in the area of operations. Link connections among these nodes represent routes and, therefore, can describe travel time. The combination of nodes and links provides the planner with a picture of the deployment that shows how all of his force elements move through the area of operations in time and space.

(2) The second level of modeling takes advantage of the node-link structure of SOTACA. This structure requires only that the user conceptually differentiate between nodes and links that represent geographical places and those that represent other activities or processes which only consume time. While this is a more abstract use of the node-link structure, it allows the planner to use this network framework to flesh out his plan by including activities that take elements of his force and time (but not necessarily movement) to execute. He can then sense how the described activity fits into the overall flow of the larger operation. Activity representation in SOTACA will be discussed in paragraph 3d.

(3) This combination of movement and activity representation using SOTACA is an industrial engineering approach to operational planning. The operation is broken down into a sequence of logical elements, and each of these is examined as a process that consumes time and resources. The SOTACA Model provides a visual framework to portray the staff planning time estimates of these elements. The resulting "sandtable" model (displayed on a computer screen) describes the connections in time and space among the activities involved in the operation. This depiction can facilitate a more analytical approach to the "mental wargaming" aspect of the planning process. Throughout construction of the model of a specific operation, it is the process of identifying activities in time and space, discussing them with the appropriate experts, and then properly describing them in model terms that give the model validity. The questions that must be answered during this

construction process assist the planner in "thinking through" the plan. The commander or staff can then view the sequence of activities and change, review, or confirm the operation. The completed model of the operation reflects the concept of the operation and includes the necessary nodes and links that fully describe the proposed course of action. The commander and/or staff can continue to use the model to reevaluate or refine competing courses of action.

b. Describing the Area of Operations

(1) The planner's first step in using SOTACA to analyze an operation is to specify the latitude and longitude of the major geographical points of interest in the area of operations. These latitude/longitude points become the initial set of nodes in the model and serve to geographically "scope" the operation.

(2) The transportation links which logically connect the geographic nodes must next be specified. Initial link distances shown on the SOTACA map are straight line distances between the connected latitude/longitude coordinates of the specified nodes. The planner must examine these distances and alter them if necessary based on planned flight paths, road distances, cross-country routes, etc.

(3) Each link is uniquely identified by describing the type of transportation connection or planned flight path profile, and expected average ground or air speed appropriate between the link's two nodes. Creation of these links will raise questions regarding specific flight paths, fuel consumption, threat environment, transport loading, etc., that require consideration in the planning process. The intent is that link transit times for a particular type of transportation reflect planned passage times based on detailed expert work. The link distances shown on the map should represent the actual route distance to be traveled for the link type of transport. Likewise, link speeds are the average speeds for that type of transport movement.

c. An Example of Geographic Modeling

(1) Consider the proposed flight of a helicopter from point A to point B. The connection between these two points in the SOTACA Model is a combination of speed and distance: in other words, time. To determine this time, the planner must consider when the aircraft could first leave "A" and when it must be at "B". He should have aviators plan flight paths and profiles that fit this time window. The planner must be able to specify to the aviators the expected visibility, threat conditions, aircraft loads, fuel availability, and a multitude of other factors which influence how long it will take an aircraft to move from point A to B. Though only speed and distance appear in the SOTACA Model of the operation, the resultant figures that are used should be the best expert estimates available. The process of deriving those figures and the data collected in the process of developing the estimates are essential elements of the modeling methodology and are among the major benefits of using SOTACA.

(2) The combination of geographical nodes and connecting links gives the planner a picture of the operations area that describes it in time and space. The representation of activities that occur at a particular geographical node, discussed next, is a more abstract and nonstandard use of the SOTACA Model.

d. **Describing Activities**

(1) The focus of describing operational processes at each node is to identify those activities that use time, are of interest to the planner, and, in the aggregate, sufficiently describe the operation. These activities must be portrayed in the context of other activities occurring at that location. **An important caution:** the user must maintain a distinction between geographic nodes and activity nodes. Geographic nodes permit examination of the time-distance flow of the operation in the area of interest. Activity nodes permit examination of activities at a specific geographic location.

(2) The key to effectively describing an operational process is to identify the elements concerned (units), their activities and times, and what (if any) relationship exists among them.

(3) While link distances and speeds between geographic nodes should portray actual data, activity nodes and links should only portray the amount of time an activity is expected to take. Link speeds and distances should be scaled to support this notion. For example, if the SOTACA rail, river, and road "fair" link speeds are set at 60 km/hour, these links will portray activity times in minutes as the length of the link in kilometers. For example, a link distance of 40 km divided by 60 km/hour is equal to two-thirds of an hour or 40 minutes. Thus, the 40 km link distance can be directly thought of as 40 minutes with this convenient choice of link speeds. The use of rail, river, and road link types provides the option of allowing multiple times for a process. In this manner, alternative situations and their impact on a course of action can be examined.

e. **Example of Activity Modeling: a Forward Arm and Refuel Point (FARP).** Figure 1 represents a FARP where four helicopters are to refuel. The FARP has four pumps, each of which can refuel a helicopter in 10 minutes. If either two or three pumps are operational, then it will take 20 minutes to refuel the flight. If only one pump is operational, then it will take at least 40 minutes to refuel the four helicopters. In actuality, it may take more than 40 minutes (four times the time to refuel one helicopter) due to a need to juggle helicopters at the FARP. This is another instance where the estimation of times must be based on expert planning and experience for the SOTACA representation to have validity and credibility.

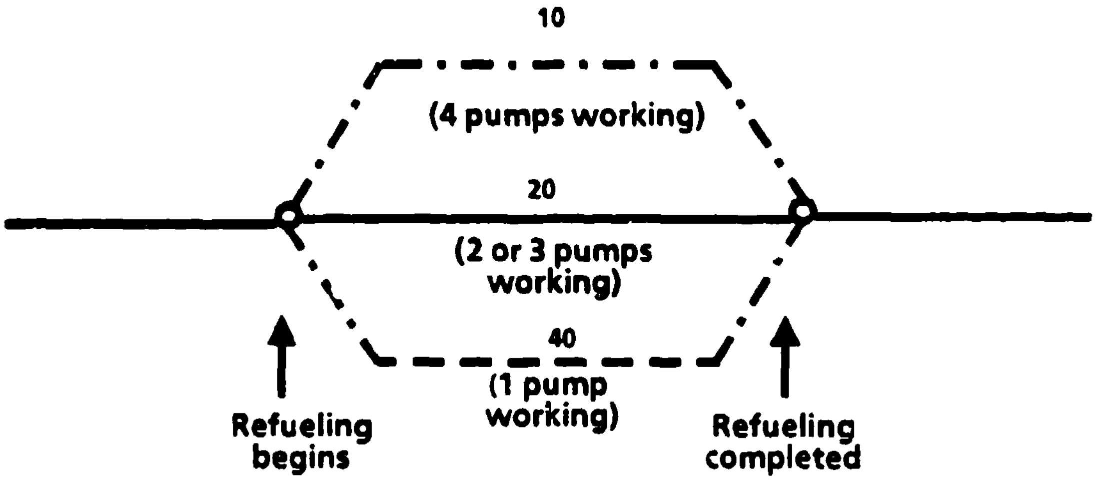

Figure 1. Forward Arm and Refuel Point (FARP) Network

4. EXAMPLE - THE IRANIAN RESCUE MISSION

a. Overview

(1) The Iranian hostage mission in 1979 provides an example of the use of SOTACA to describe an operation. Data used in this example are from unclassified sources listed in the bibliography.

(2) The rescue operation was staged from Qena, Egypt and involved the use of Masirah Airfield, Oman. Eight CH53 Sea Stallion helicopters were to fly from the USS Nimitz about 600 nautical miles to an intermediate support base called "Desert One" located in a remote area of Iran. Six C130 aircraft containing fuel and the rescue force were to fly from Masirah and rendezvous with the helicopters. The loaded helicopters would fly the rescue force to a hidden location about 50 miles from Teheran; the helicopters would then move to another concealed location about 15 kilometers away. All of these actions were to be completed during the hours of darkness on the first day of the mission.

(3) After dark on the second day, the rescue force was to move by vehicle through Teheran to the US Embassy. The helicopters were to be orbiting north of the city waiting for word to come in. Simultaneously, Army Rangers were to begin the capture of a deserted airfield at Manzariyeh, about 90 kilometers southwest of Teheran. The Rangers were to have flown to Manzariyeh on C130s from Oman along with AC130 gunships. The gunships would then have continued on to support the embassy assault and the extraction of hostages and the assault force.

(4) Following extraction from the vicinity of the embassy, the helicopters would fly the hostages and rescue force to Manzariyeh for transfer to waiting fixed wing aircraft. The helicopters would be destroyed on the ground and the remaining aircraft would depart for Qena, Egypt.

b. Model of Operation

(1) **Geographic Locations.** The key geographical locations involved in the rescue attempt were the carrier Nimitz in the Indian Ocean off the coast of Iran, the intermediate support base called "Desert One," a rendezvous point and helicopter staging area about 50 miles southeast of Teheran, the US Embassy in Teheran, and a deserted airfield at Manzariyeh, Iran. Geographical points of interest outside of the country included Qena, Egypt and Masirah, Oman. These locations are depicted on the SOTACA-generated map at Figure 2.

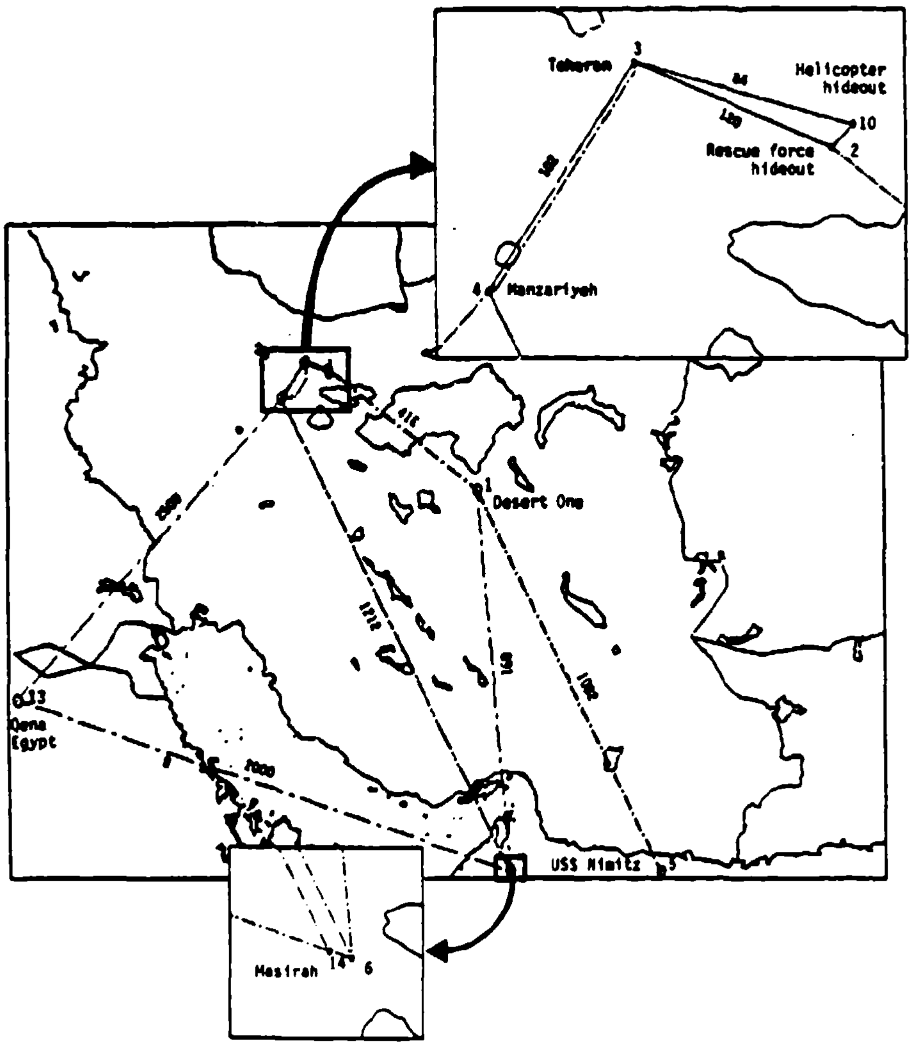

Figure 2. SOTACA Map of Geographical Area of Operations

(2) **Modeling Techniques.** Figure 2 illustrates some useful SOTACA modeling techniques.

(a) **Multiple Nodes at a Single Geographic Location.** Multiple nodes allow the representation of multiple flight paths (links) between locations. This would be necessary when a different flight path (or profile) is used on egress from a target as opposed to the ingress leg of the trip. In Figure 2, the link from node 6 to node 4 represents low level, radar avoiding, surreptitious entry into Iranian airspace by the airfield seizure and extraction aircraft en route to the Manzariyeh airfield. The link from node 4 to node 14 represents the return flight path which would be expected to be conducted under different circumstances.

(b) **Nonscale Links and Notional Locations.** In Figure 2, Qena, Egypt is actually off the map. However, it can be represented by node 13 with its connecting links reflecting the expected flight distances from Qena. This allows widely separated points to be considered visually in the model without requiring a very small-scale map to be used to accommodate a few outlying points.

(3) **Activities Modeled.** Activities described by SOTACA in this example are the airfield seizure at Manzariyeh and a notional building assault to rescue hostages. These activities are only used to portray the flexibility of SOTACA as a planning tool and do not necessarily represent actual tactics or doctrine.

(a) **Airfield Seizure**

1. Figure 3 could represent the planned seizure of the airfield at Manzariyeh by Army Rangers. The nodes represent activities, the links represent the passage of time. Node 21 is the beginning of the assault. Distances and link speeds have been scaled so that the link distances shown represent time in minutes.

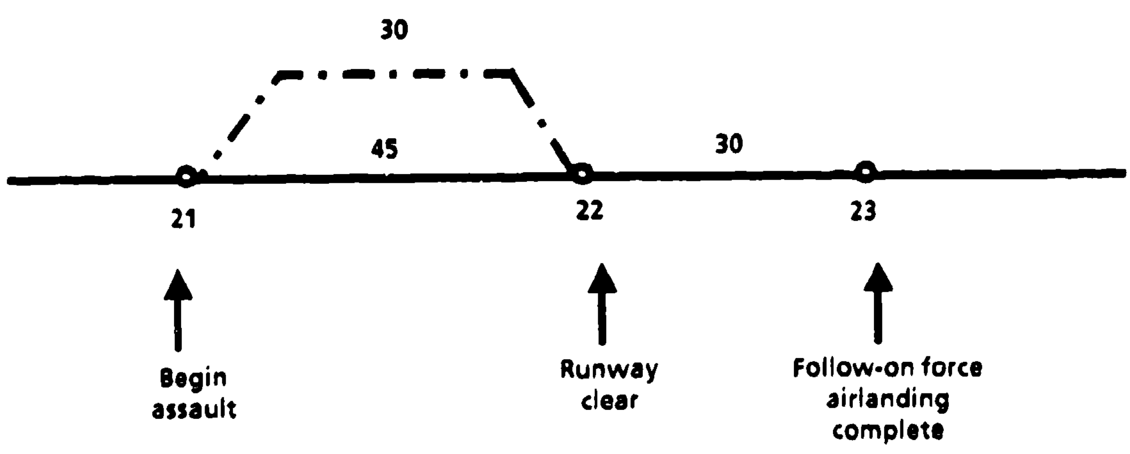

Figure 3. Example Airfield Seizure Network

2. The time between nodes 21 and 22 represent the initial airfield seizure; the 30-minute time link is for an airlanding (runway is clear); the 45-minute time link is for an initial parachute seizure to clear the runway for follow-on airlandings. The 30-minute time link between nodes 22 and 23 represents airlanding the main airfield security force. This reflects a staff estimate of 60 to 75 minutes to secure the airfield, depending on the type of initial assault. This represents airfield seizure in its most simplistic fashion. Detailed study of the tasks to be performed and the units to be used for an airlanding assault might provide the additional information shown in Table 1. Again, it must be pointed out that this is a notional example and is not intended to encompass all of the actions, time, and sequences of an actual mission.

Table 1. Mission Task Timelines

Timeline for initial seizure (airlanding)

Elapsed time (in minutes)	0	5	10	15	20	25	30
A/C #1		**Activities (in 5-minute increments of elapsed time)**					
1PLT	Land	Off-load	To tower				
2PLT	Land	Off-load	To Pos 1	Emplace 2MGs			
3PLT	Land	Off-load	To Pos 2	To Pos 2	To Pos 2	Empl MG, TOW	
4PLT	Land	Off-load	To Pos 3	To Pos 3	To Pos 3	Empl Mortar	Empl Mortar
A/C #2							
5PLT	Wait	Land	Off-load	To Pos 4	To Pos 4	Empl 2MGs	
6PLT	Wait	Land	Off-load	To Pos 5	Empl Commo	Empl Commo	Empl Commo
7PLT	Wait	Land	Off-load	To Pos 6	To Pos 6		
8PLT	Wait	Land	Off-	To Pos 6	To Pos 6		

3. Recall that, at the activity level, we are using SOTACA to describe a time process. Figure 4, a diagram of the above description, is an alternative portrayal of the activity.

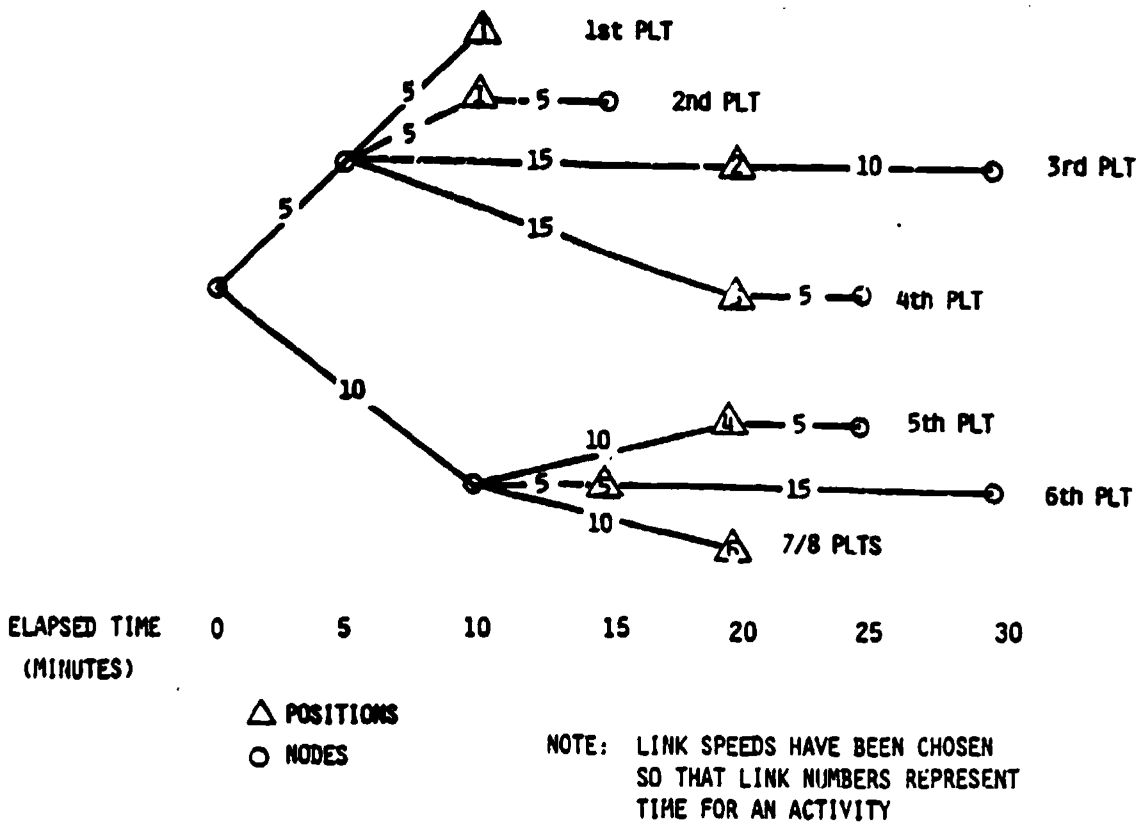

Figure 4. Mission Task Timeline Diagram

4. Though it is not necessary in terms of operating the model, the nodes have been aligned and the links scaled to provide a more accurate (and visually pleasing) flow chart of the process represented. This provides a picture of the simultaneity of actions of the described groups. For example, in the above case, only two of the eight platoons are in position 20-25 minutes into the operation. This may be viewed as taking too long and may thus require restructuring the targets or offloading points when the planner "sees" the totality of his plan visually displayed.

5. If desired, this airfield assault could be portrayed by a different graphical description using other SOTACA nodes and links to draw a picture of the objective area. Figure 5 portrays the airfield seizure as a picture of movement in the objective area. The links would still represent time. This is just a different way of representing the same expert-generated information and is more closely akin to a traditional sandtable approach with the added dimension of time portrayed.

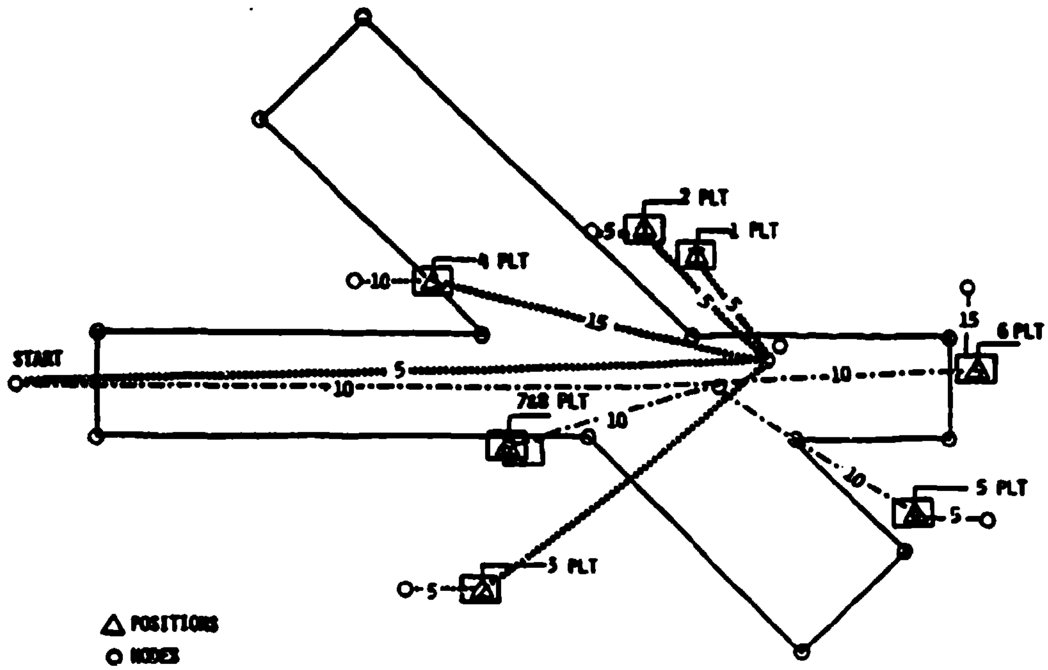

Figure 5. Airfield Seizure Movement Picture

6. The link times and units are the same as in the previous example. However, now the picture is suitable for orienting personnel involved in the operation, using as a background the physical features of the target.

7. Each of the activities represented requires a detailed examination of resources required, travel times, skills needed, signals required, and other typical planning considerations. Each of the activities could have further been broken down and depicted in the node-link format. However, a standard of reasonableness needs to be applied. This use of SOTACA is only a rough-cut examination of courses of action based on best estimates by experts. Below some level of detail (which will vary among problems, planners, and decisionmakers), the activity shown in SOTACA will become obscured by detail and will not highlight the flow of an operation. This is not to imply that such detailed planning should not be done, but only that it may not be productive to include it in the SOTACA Model.

8. It is important to point out that the encounters in the applications described in this paper involve force elements that are small and highly specialized. Combat actions are short in duration--they occur in

seconds or minutes rather than hours or days--and they are of a win-lose nature. Use of SOTACA's attrition mechanism in this situation can be potentially misleading. For example, in the airfield seizure being described here a mission for one of the platoons might be the elimination of an outpost. The essence of the planner's task is to plan the successful elimination of this outpost. He knows the timeframe within which this action should be completed and will plan for sufficient force to be at the right time and place to ensure the outpost is eliminated. He is, in fact, making a judgmental calculation of the attrition expected and planning accordingly. SOTACA's attrition mechanism was not used because of the extremely detailed resolution of the infantry-type combat represented in this example. The SOTACA attrition methodology requires as input attrition data for a representative conflict between combatants of the type and environment to be simulated. This basic information is then extrapolated for varying numbers of combatants. In the very detailed combat suggested in this example, the extrapolation of a single sample across disparate combat situations (e.g., assaulting an airfield control tower, assaulting a bunker, defending an access route against counterattack, defeating an armored car attack) would be inappropriate. If the situations were essentially homogeneous except for varying densities of weapon systems (typically the case in more aggregate force situations--e.g., corps/division level conflict), the extrapolation is appropriate. At the level of detail represented here, the planner's estimates of the outcome of the unique individual conflicts are more appropriate than the aggregate estimates of a generalized attrition methodology.

(b) Assault on a Building

1. A planner can represent an assault on a building in the same manner as in the airfield example. However, since the distances are shorter and speeds are usually of individual human beings (though estimated by experts), caution is advised in use of the results. The operations model constructed with SOTACA can provide a planning estimate only of what is expected to occur--and in what order--rather than a prediction of the actual outcome. As in the aircraft example, the constructed model will only reflect the staff planners' inputs. No information, relationships, or truth is inherent in, or provided by, the model.

2. The objective discussed here refers to a building, bunker, or other structure which must be entered in order to perform some action. Usually multiple people are involved in the attack and defense of such an objective. Attackers and defenders can be small groups of personnel or individuals. The possible routes available to the attackers are known to the planner. Subject matter experts can reliably estimate times by considering factors such as individual loads, lighting conditions, forced entry time delays, and distances. Figure 6 describes such an objective.

3. Nodes and links are used to portray the outlines of the objective in the same manner as was done in the airfield seizure example. A picture of the structure/area of interest is drawn. Note that this is for orientation only because the scale of work makes the SOTACA map data base useless as a geographic background. A convenient scale is used on the screen to logically portray the target. Another set of nodes and links are used to portray personnel routes. A node is used for each doorway or entry location of interest. Distances can be depicted using one of two available methods:

- Represent the actual distances in meters and use available personnel movement time.

- Use a constant movement speed (e.g., 1 meter/second) and portray all distances on the screen in terms of movement seconds. This approach is actually the easier--and more flexible.

4. The result is a picture (again, a sandtable) of who does what, when, and where. The planner gets a sensing of the expected "flow" of the operation. Figure 6 is an example of a building to be cleared by a five-man team who enter through a door (node 2) and move to each room in the building. The example picture in Figure 6 is frozen 7 seconds into the clearing operation. Team member A has cleared his initial room and is moving to the doorway at node 11. Team member B has moved through the doorways at node 11 and 20 and is clearing his room. Team member C has just entered the room he is to clear (entering through the doorway at node 13). Team member D is in the doorway (node 17) of the room he is to clear. Team member E is holding in his position, providing backup to the other members. Running this example in SOTACA provides a picture of the simultaneity of expected action in such an operation.

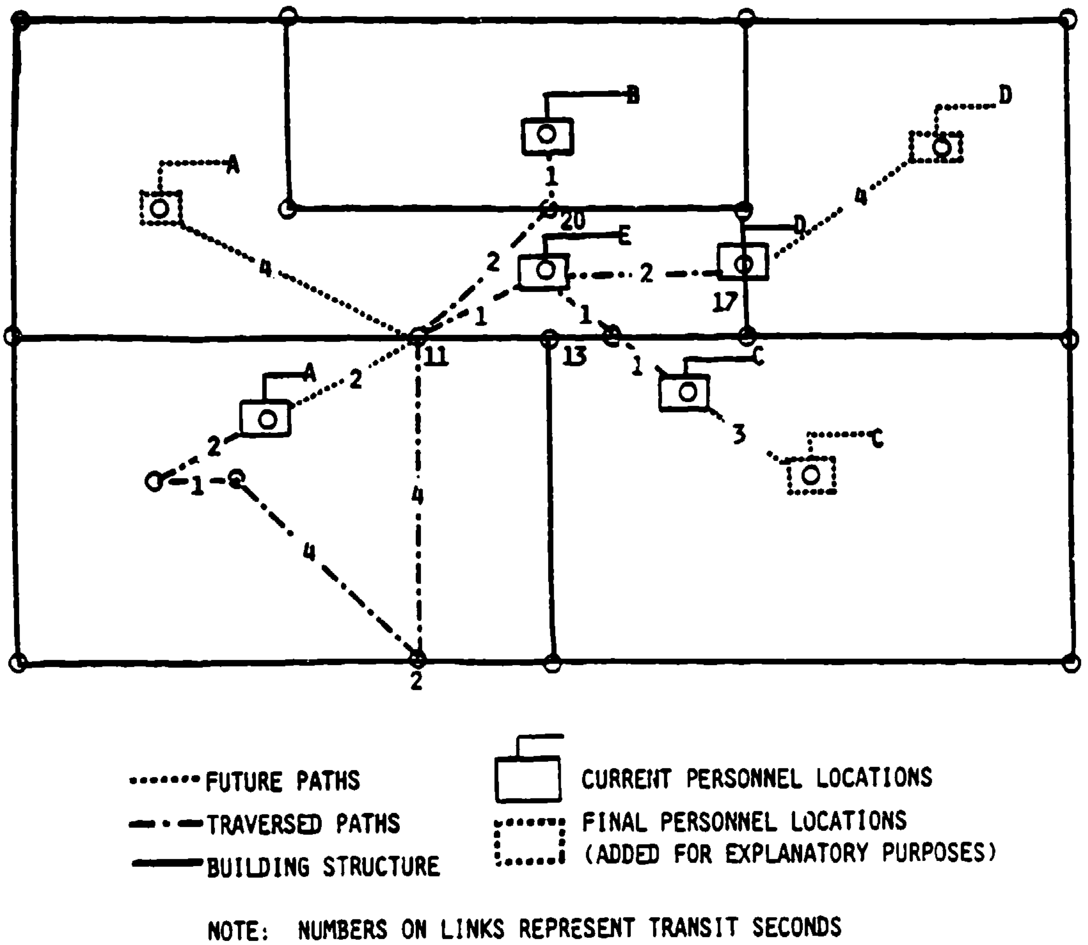

Figure 6. Assault on a Building

5. **SUMMARY.** In this application, a model constructed with SOTACA is the result of staff planning at each step. Nothing is buried in the model or hidden from the user. SOTACA's main advantage is that it offers the capability to describe and view dynamically an operation in terms of time and distance. In building such a node-link network, the planner is provided a framework within which he must construct a complete and coherent course of action. If he has not constructed a complete path for the operation from departure to recovery, the model will simply not work. This use of SOTACA is only descriptive and is in no way predictive; no implication should be drawn that a course of action will proceed in reality exactly as described.

APPENDIX A

BIBLIOGRAPHY

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APPENDIX B

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STATE OF THE ART CONTINGENCY ANALYSIS (SOTACA) MODEL TECHNIQUES	STUDY SUMMARY CAA-TP-87-12

THE REASON FOR CONDUCTING THE STUDY was to document a nonstandard use for the State of the Art Contingency Analysis (SOTACA) Model developed by the Conflict Analysis Center.

THE PRINCIPAL ACCOMPLISHMENT of the study was the development of a methodology by which time-oriented processes can be represented in SOTACA.

THE PRINCIPAL FINDINGS of the study were that:

(1) Time-oriented processes can be represented in conjunction with spatial movement in SOTACA.

(2) The combination of spatial and time representation in SOTACA allows a planner to portray the results of staff planning estimates dynamically in a sandtable-like manner.

THE PRINCIPAL LIMITATIONS of this use of SOTACA are that:

(1) SOTACA's network basis is a simplification of the operation described.

(2) This technique only uses the model as a framework to reflect the results of staff planning.

THE BASIC APPROACH was to exploit the node-arc structure of SOTACA to represent the passage of time without spatial movement in the model. This was done by distinguishing between nodes and arcs that represent movement from one place to another and those that only represent the time required to complete an activity or process.

THE STUDY SPONSOR was the Director, US Army Concepts Analysis Agency.

THE STUDY was conducted by MAJ Gerald J. Wilkes, Conflict Analysis Center, US Army Concepts Analysis Agency.

COMMENTS AND QUESTIONS may be forwarded to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-SP, 8120 Woodmont Avenue, Bethesda, MD 20814-2797.